

Axisymmetric Numerical Modeling of Pulse Detonation Rocket Engines

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ABSTRACT

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Pulse detonation rocket engines (PDREs) have generated research interest in recent years [1] as a chemical propulsion system potentially offering improved performance and reduced complexity compared to conventional rocket engines. The detonative mode of combustion employed by these devices offers a thermodynamic advantage over the constant-pressure deflagrative combustion mode used in conventional rocket engines and gas turbines. However, while this theoretical advantage has spurred considerable interest in building PDRE devices, the unsteady blowdown process intrinsic to the PDRE has made realistic estimates of the actual propulsive performance problematic. The recent review article by Kailasanath [2] highlights some of the progress that has been made in comparing the available experimental measurements with analytical and numerical models.

In recent work by the author [3], a quasi-one-dimensional, finite rate chemistry CFD model was utilized to study the gasdynamics and performance characteristics of PDREs over a range of blowdown pressure ratios from 1-1000. Models of this type are computationally inexpensive, and enable first-order parametric studies of the effect of several nozzle and extension geometries on PDRE performance over a wide range of conditions. However, the quasi-one-dimensional approach is limited in that it cannot properly capture the multidimensional blast wave and flow expansion downstream of the PDRE, nor can it resolve nozzle flow separation if present. Moreover, the previous work was limited to single-pulse calculations.

In this paper, an axisymmetric finite rate chemistry model is described and utilized to study these issues in greater detail. Example Mach number contour plots showing the multidimensional blast wave and nozzle exhaust plume are shown in Figure 1. The performance results are compared with the quasi-one-dimensional results from the previous paper. Both Euler and Navier-Stokes solutions are calculated in order to determine the effect of viscous effects in the nozzle flowfield. Additionally, comparisons of the model results to performance data from CalTech [4], as well as experimental flowfield measurements from Stanford University [5-6], are also reported.

REFERENCES

1. Bratkovich, T. E., Aamio, M. J., Williams, J. T., and Bussing, T. R. A., "An Introduction to Pulse Detonation Rocket Engines," AIAA paper 97-2742, July, 1997.
2. Kailasanath, K., "A review of PDE Research – Performance Estimates," AIAA paper 2001-0474, January, 2001.
3. Morris, C. I., "Numerical Modeling of Single-Pulse Gasdynamics and Performance of Pulse Detonation Rocket Engines," *Journal of Propulsion Power* (to be published), see also AIAA paper 2004-0463, January, 2004.
4. Cooper, M. and Shepherd, J. E., "The Effect of Transient Nozzle Flow on Detonation Tube Impulse," AIAA paper 2004-3914, July, 2004.
5. Mattison, D. W., Oehlschlaeger, M. A., Morris, C. I., Owens, Z. C., Barbour, E. A., Jeffries, J. B., and Hanson, R. K., "Evaluation of Pulse Detonation Engine Modeling Using Laser-Based Temperature and OH Concentration Measurements," *Proceedings of the Combustion Institute*, Vol. 30, in press, 2004.
6. Barbour, E. A., Hanson, R. K., Morris, C. I., and Radulescu, M. I., "A Pulsed Detonation Tube with a Converging-Diverging Nozzle Operating at Different Pressure Ratios," AIAA paper 2005-1307, January, 2005.

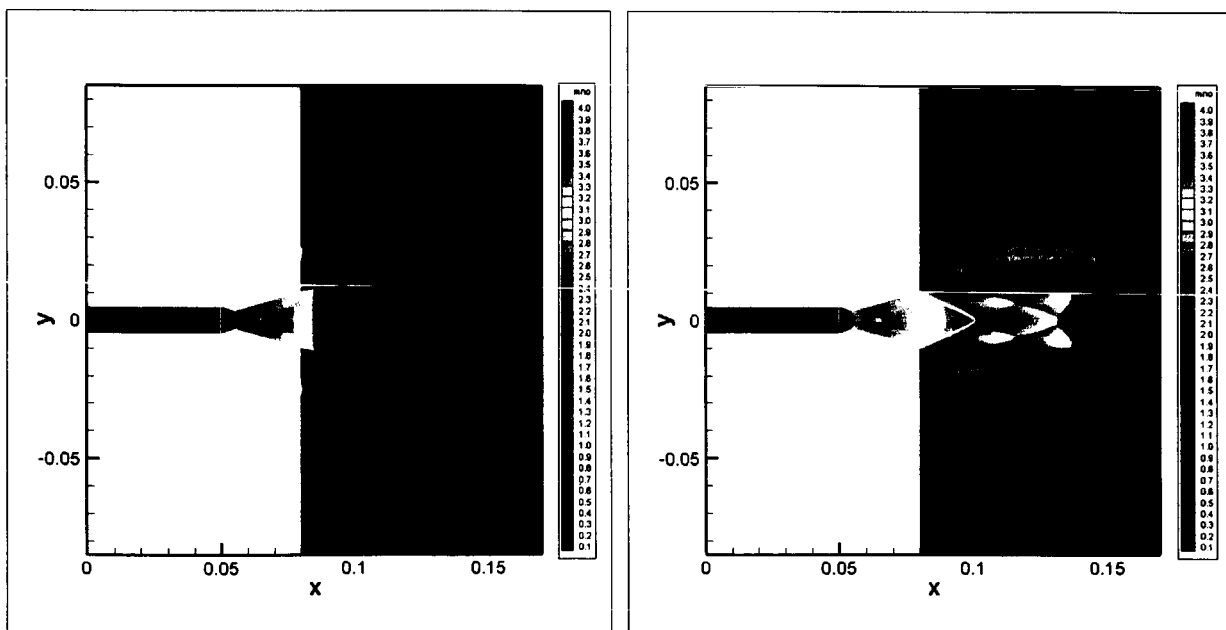


Figure 1 – Example Mach number contour plots showing PDRE blowdown flowfield 50 μ s (left panel) and 130 μ s (right panel) after detonation initiation. Propellant mixture: stoichiometric H_2-O_2 at $P_{ini} = 1$ atm, $T_{ini} = 300$ K. Ambient gas: N_2 at $P_{amb} = 0.1$ atm, $T_{amb} = 300$ K.